JC03 Rec'd PCT/PTO 18 APR 2001

FORM PTO-1390 US DEPARTMENT OF COMMERCE REV. 5-93 PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**		ATTORNEYS DOCKET NUMBER **P01,0059** U.S. APPLICATION NO. (if known, see 37 CFR 1.5) 09/807766
INTERNATIONAL APPLICATION NO. **PCT/DE99/03178**	INTERNATIONAL FILING DATE **01 OCTOBER 1999**	PRIORITY DATE CLAIMED **23 OCTOBER 1998**

TITLE OF INVENTION

METHOD FOR CHANNEL-BY-CHANNEL ADJUSTMENT OF TRANSMITTED SIGNAL POWER IN AN OPTICAL WAVELENGTH-DIVISION MULTIPLEX TRANSMISSION SYSTEM

APPLICANT(S) FOR DO/EO/US

WEISKE, et al.

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay.
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. §371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☒ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98; **(PTO 1449, Prior Art, Search Report, References).**
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 C.F.R. 3.28 and 3.31 is included. **(SEE ATTACHED ENVELOPE)**
13. ☒ Preliminary Amendment
    ☐ A SECOND or SUBSEQUENT preliminary amendment.
14. ☒ A substitute specification and substitute specification mark-up.
15. ☒ A change of address letter attached to the Declaration.
16. ☒ Other items or information:
    a. ☒ Submission of Drawings
    b. ☒ EXPRESS MAIL #EL 843728393 US dated April 18, 2001

JC02 Rec'd PCT/PTO 18 APR 2001

U.S. APPLICATION NO. (if known, see 37 C.F.R. 1.5) 09/807766	INTERNATIONAL APPLICATION NO PCT/DE99/03178	ATTORNEY'S DOCKET NUMBER P01,0059

17. ☒ The following fees are submitted:

BASIC NATIONAL FEE (37 C.F.R. 1.492(a)(1)-(5):

Search Report has been prepared by the EPO or JPO $860.00

International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) $690.00

No international preliminary examination fee paid to USPTO (37 C.F.R. 1.482) but international search fee paid to USPTO (37 C.F.R. 1.445(a)(2) $710.00

Neither international preliminary examination fee (37 C.F.R. 1.482) nor international search fee (37 C.F.R. 1.445(a)(2) paid to USPTO $1000.00

International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $ 100.00

				CALCULATIONS	PTO USE ONLY
ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 860.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 C.F.R. 1.492(e)).				$	
Claims	Number Filed	Number Extra	Rate		
Total Claims	07 - 20 =	0	X $ 18.00	$	
Independent Claims	02 - 3 =	0	X $ 80.00	$	
Multiple Dependent Claims			$270.00 +	$	
TOTAL OF ABOVE CALCULATIONS =				$ 860.00	
Reduction by ½ for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 C.F.R. 1.9, 1.27, 1.28)				$	
SUBTOTAL =				$ 860.00	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$ 860.00	
Fee for recording the enclosed assignment (37 C.F.R. 1.21(h). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. 3.28, 3.31). $40.00 per property +					
TOTAL FEES ENCLOSED =				$ 860.00	
				Amount to be refunded	$
				charged	$

a. ☒ A check in the amount of $ 860.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ____________ in the amount of $ ________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 50-1519. **A duplicate copy of this sheet is enclosed.**

NOTE: Where an appropriate time limit under 37 C.F.R. 1.494 or 1.495 has not been met, a petition to revive (37 C.F.R. 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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BOX PCT

IN THE UNITED STATES DESIGNATED/ELECTED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY – CHAPTER II

AMENDMENT "A" PRIOR TO ACTION AND SUBMISSION OF SUBSTITUTE SPECIFICATION

APPLICANT(S):	WEISKE, et al.
ATTORNEY DOCKET NO:	P01,0059
INTERNATIONAL APPLICATION NO:	PCT/DE99/03178
INTERNATIONAL FILING DATE:	1 OCT 1999
INVENTION:	METHOD FOR CHANNEL-BY-CHANNEL ADJUSTMENT OF TRANSMITTED SIGNAL POWER IN AN OPTICAL WAVELENGTH-DIVISION MULTIPLEX TRANSMISSION SYSTEM

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

Applicants herewith submit an amendment and substitute specification in the captioned PCT application, and respectfully request entry of same prior to examination in the United States National Stage.

IN THE SPECIFICATION

Cancel the specification as filed and insert therefore the substitute specification provided herewith.

IN THE CLAIMS

Cancel the claims as filed, and insert therefore new claims 8 - 14 as follows:

- - What is claimed is:

8. A method for channel-specific adjustment of transmitted signal power levels in an optical wavelength-division multiplex transmission system, the method comprising the steps of:

determining transmission characteristics for each transmission channel;

determining on a channel-specific basis, signal power levels of associated transmitted signals, if the signal power levels or the signal-to-noise ratios of individual received signals are the same;

determining the transmission-end dynamic range, if a maximum permissible dynamic range at the transmission end is exceeded;

determining individual power discrepancies of the transmitted signals from the mean transmitted signal power level;

reducing by calculation the individual power discrepancies of the transmitted signals using a transmission compression factor, which is the same for all the transmitted signals;

complying with the maximum permissible dynamic range such that the required transmission signal power levels are recalculated; and

setting newly calculated compressed transmitted signal power levels.

9. The method as claimed in claim 8, further comprising the step of:

keeping a total maximum permissible total transmitted signal power level of all the transmitted signals at least approximately constant.

10. The method as claimed in claim 9, further comprising the step of:

determining transmitted signal power levels of the transmitted signals and transmission-end values derived therefrom by measuring the received signal power levels of the received signals and from the transmission characteristics of the transmission channels.

11. A method for channel-specific adjustment of transmitted signal power levels in an optical wavelength-division multiplex transmission system, the method comprising the steps of:

determining transmission characteristics for each transmission channel;

determined on a channel-specific basis, power levels of the associated transmitted signals, if the signal-to-noise ratios of the individual received signals are the same;

determining the reception-end dynamic range, if a maximum permissible reception-end dynamic range is exceeded;

determining individual power discrepancies of the transmitted signal power levels from the mean received power level;

reducing by calculation individual power discrepancies of the received signals using a compression factor which is the same for all received signals, such that a maximum permissible dynamic range at the reception end is

complied with;

calculating the required new transmitted signal power levels, if necessary;

carrying out transmission-end power correction using a transmission-end correction factor which needs to be calculated; and

setting newly calculated compressed transmission signal power levels.

12. The method as claimed in claim 11, further comprising the step of: keeping a total received signal power level of all received signals and/or the total transmitted signal power level of all transmitted signals at least approximately constant.

13. The method as claimed in claim 12, further comprising the step of:

determining the transmitted signal power levels of the transmitted signals and transmission-end values, derived from them, by measurement of the received signal power levels of the received signals and from the transmission characteristics of the transmission channels.

14. The method as claimed in claim 13, further comprising the steps of:

calculating the transmission-end correction factor from the ratio of a previous transmission-end mean level value to a transmission-end mean level value determined from a new transmitted signal power level;

changing the individual signal power levels of transmitted signals using the transmission-end correction factor, which is the same for all transmitted signals; and

keeping the total maximum permissible total transmitted signal power level of all transmitted signals at least approximately constant. - -

IN THE ABSTRACT

Cancel the Abstract as filed, and insert therefore on a separate page, the following Abstract of the Disclosure:

- - **ABSTRACT OF THE DISCLOSURE**

For exact level balancing or signal-to-noise ratio balancing of received signals in a wave-length-division multiplex transmission system, the associated transmitted signal power levels are adjusted. If the maximum permissible dynamic range is exceeded, the individual transmitted signal power levels are compressed, while the total transmitted signal power level is kept at least approximately constant. - -

REMARKS

A substitute specification and an Abstract of the Disclosure are provided herewith which make editorial changes in order to conform to standard US practice. A marked-up copy of the specification is also provided reflecting the changes made.

In addition, the claims as filed have been canceled and replaced by new claims that more clearly set forth the subject matt of Applicants' invention.

No new matter has been inserted into the application.

Applicants submit that this application is in proper condition for examination in the United States national Examination Stage, which action is earnestly solicited.

Respectfully submitted,

Steven H. Noll

Steven H. Noll (Reg. No. 28,982)

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Substitute Specification:

- - METHOD FOR CHANNEL-BY-CHANNEL ADJUSTMENT OF TRANSMITTED SIGNAL POWER LEVELS IN AN OPTICAL WAVELENGTH-DIVISION MULTIPLEX TRANSMISSION SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention pertains to optical wavelength division multiplex transmission systems in general. Specifically, the present invention pertains to adjustment of transmitted signal power levels in optical wavelength division multiplex transmission systems.

Discussion of the Related Art:

Owing to the wavelength dependency of optical amplifiers, optical wavelength-division multiplex transmission systems have losses in the transmission fibers and in passive optical components as well as attenuation levels which differ due to non-linear effects such as signal coupling resulting from stimulated Raman scatter in general for the various signals and channels. In an optical transmission path which comprises a number of path sections having a number of fiber amplifiers, these effects can become additive. As a consequence of this, at the receiving end, the weaker optical signals are no longer detected without faults by the optical receiver since their levels are too low or since their optical signal-to-noise ratio

(OSNR) is too low. On the other hand, the maximum permissible input level of the optical receiver may be exceeded by a signal which is attenuated to a lesser extent.

One method, which is used in existing optical transmission systems, for compensating for the different levels or OSNR values is corresponding initial compensation at the transmission end, which is referred to as preemphasis. In this case the level or OSNR distribution of the channels/signals at the reception end is measured using an optical spectrum analyzer, and the level at the transmission end is raised for signals which arrive with severe attenuation at the receiver, while the level of more powerful signals is correspondingly reduced, to ensure that all the received signals have the same power level, also referred to as level balance, or the same optical signal-to-noise ratio (OSNR balance) at the reception end. The raising or lowering of the transmitted signal level for each channel or for each transmitted signal is generally selected such that the total transmitted signal power level , that is the total of the power levels of all the transmitted signals and of the total signal, remains unchanged at the start of the optical path or does not exceed a maximum value.

Suitable algorithms for level and OSNR balancing are described in the article "Equalization in Amplified WDM Lightwave Transmission Systems" appearing in IEEE Photonics, Technology Letters, Vol. 4, No. 8, August 1992, pages 920 to 922.

However, disadvantages can occur if exactly implemented level or OSNR compensation is used. One such disadvantages is that, owing to the wavelength dependency of the path loss, complete level balancing for the reception end can lead

to an excessively high level dynamic range at the transmitting end. Hence, an excessively large quotient between the maximum and minimum channel power level can occur. There is then a risk of signals with a raised transmitted power level being distorted by non-linear effects in the fibers and/or of transmitted signals with a greatly reduced level actually falling below the minimum input power level of an optical amplifier, which would result in considerable signal distortion due to noise.

Complete OSNR balancing for the reception end can also lead to an excessive level dynamic range at the transmitting end. In addition, there is a risk of the maximum permissible input level range of one or more of the connected optical receivers being exceeded or undershot.

A method and arrangement for adjusting identical signal levels is shown in US Patent 5,815,299. In the method, the average level of all the transmitted signals and the level of the weakest signal are determined. The other signals are attenuated as a function of the difference between the average level and the level of the weakest signal. However, this reduces the average level and thus the quality of all the other channels. Such a method admittedly leads to identical levels in all the channels, but does not optimally utilize the maximum possible dynamic range and thus does not achieve optimum transmission quality or optimum range.

In general, exact level balancing at the reception end is not required, since the connected optical receivers have a considerable level dynamic range in which they operate optimally. In the same way, exact OSNR balancing is not required, provided appropriate system margins are available. In this case, a method which considers

only the dynamic range of the transmitted signals would be optimal. Since, systems of this type operate at an optimum or maximum permissible total power level, it is advantageous for this level to remain constant in any compression of individual transmitted signal power levels which may be required.

For OSNR balancing however, the maximum permissible dynamic range at the reception end must also be checked, and if necessary, the received signal power levels are adapted by compression. This is done by changing the power level of the individual transmitted signals, and compliance with the transmission-end dynamic range must be checked once again and, if necessary, changed.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method for channel-by-channel adjustment of transmitted signal power levels in which the transmission-end dynamic range is complied with without unnecessarily adversely affecting the transmission quality.

It is another object of the invention to provide a method for channel-by-channel adjustment of transmitted signal power levels in which reception-end dynamic range for exact OSNR balancing is achieved.

These and other objects of the invention will become apparent from careful review of the following detailed description of the preferred embodiments, which is to be read in conjunction with a review of the accompanying drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows an exemplary wavelength division multiplex transmission system with dynamic range compression;

Figure 2 shows a flowchart for transmission-end dynamic range compression; and

Figure 3 shows a flowchart for reception-end dynamic range compression.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows a circuit diagram of a wavelength division multiplex (WDM) transmission device.

A transmission terminal TT is provided which contains a number of optical transmitters TX1 - TXn for transmitting data via channels allocated to different wavelengths. Corresponding transmitted signals S1 - Sn are passed via adjustable optical attenuators VOA1 to VOAn, and are combined by a multiplexer M to form a wavelength-division multiplex signal WMS. The signal WMS is fed into an optical fiber F and transmitted via various path sections SA1, SA2 to a receiving terminal RT. Various optical amplifiers V are provided in order to compensate for attenuation by the optical fibers.

In the receiving terminal RT, the wavelength division multiplex signal is broken

down in a demultiplexer D into individual received signals E1 - En, which are supplied to a respective optical receiver RX1 - RXn.

The wavelength division multiplex signal is split at the reception end by a coupler K, which is connected upstream of the demultiplexer, and is supplied to an optical spectrum analyzer OSA. The level and OSNR values measured by the optical spectrum analyzer OSA are passed, via a separate control channel OSC (Optical Supervisory Channel) for example, to a preemphasis controller MD in the transmission terminal. The preemphasis controller MD comprises a computation device CU and an adjustment device SD which adjusts the transmitted levels of the individual transmitted signals, for example by controlling the output power level of the optical transmitters or, in this case, by adjusting the attenuators. The computation unit can likewise be provided at the reception end.

Consider the situation in which only the transmission-end dynamic range is adjusted, on the basis of the flowchart shown in Figure 2. Individual transmitted power levels and received power levels, or transmitted power levels and reception-end signal-to-noise ratios, for short distances, the attenuations in the individual channels or the OSNR quality (signal to noise ratio/transmitted power level) generally need to be measured.

Firstly, the transmission-end power distribution also called the level distribution, is then calculated for exact level or OSNR balancing at the reception end, based on the transmission characteristics of the individual channels, as described above.

The dynamic range compression can then be started. A first step determines the magnitude of the transmission-end level dynamic range Dtx. This corresponds to the quotient of the maximum level Ptx_max and the minimum level Ptx_min of the transmitted signals, with the term level in this case meaning the power on a linear scale, for example in milliwatts.

F1) Dtx = maximum level from Ptx(i)/minimum level from Ptx(i)

i = 1, 2, ... n - Transmitted signal

A check is then carried out to determine whether the dynamic range Dtx which has been found is greater than the maximum permissible dynamic range Dtx_max. If this is not the case, no dynamic range compression is carried out. However, if this is the case, the next computation step calculates the discrepancy, that is to say the offset, of the individual signal power levels from the mean value Ptx_mean, which has been determined from the optimum or maximum permissible transmitted power level of the transmission-end wavelength division multiplex signal divided by the number of signals.

F2) deltaP_tx(i) := Ptx(i) - Ptx_mean

The next computation step determines the absolute maximum and minimum offset, in other words the offset of the strongest and weakest transmitted signal.

F3) deltaPtx_max := max(deltaPtx(i))

deltaPtx_min := min(deltaPtx(i))

The transmission compression factor is then calculated

F4) compfact_tx := Ptx_mean* (Dtx_max - 1)/

(deltaPtx_max - Dtx_max*deltaPtx_min)

This is then used to calculate the compressed levels using the following formulae:

F5) deltaPtx(i) := deltaPtx(i) * compfact_tx

Ptx(i) := Ptx_mean + deltaP_tx(i)

The dynamic range compression has thus already been calculated and the newly calculated compressed transmission levels Ptx(i) of the transmitted signals S1 to Sn can be set.

If the individual received signals E1 to En are intended to have the same signal-to-noise ratio, that is to say OSNR balancing is assumed, reception-end dynamic range compression can also be carried out, in an extended method as shown in Figure 3. The compression method is once again dependent on the transmission characteristics of each channel being known.

This makes it possible to calculate the transmission-end levels for the individual transmitted signals, the level distribution, for OSNR balancing.

The reception-end dynamic range compression starts by determining the

reception-end dynamic range Drx.

F7) Drx:= maximum level from Prx(i)/minimum level from Prx(i)

i = 1, 2, ...,n - Received signal

A check is then carried out to determine whether the maximum permissible reception-end dynamic range Drx is exceeded. If not, there is no need for reception-end dynamic range compression, and the calculated signal levels can be set at the transmission end. In general, a check of the maximum permissible transmission-end dynamic range is also required.

If the maximum permissible reception-end dynamic range Drx is exceeded, then, the discrepancies, or offsets, of the reception-end channel power levels Ptx(i) from the main value Ptx_mean are established:

F7) deltaP_rx(i) := P_rx(i) - P_rx_mean

and the maximum and minimum offsets are determined:

F8) deltaP_rx_max :=max(deltaP_rx(i))

deltaP_rxmin := min(deltaP_rx(i))

The reception-end compression factor is then calculated:

F9) compfact_rx :=Prx_mean*(Drx_max - 1)

/(deltaPrx_max - Drx_max * deltaPrx_min

The compressed reception levels are then determined:

F10) Prx(i) := Prx_mean * deltaPrx(i) * compfact_rx

The already determined channel-specific path loss Atten(i) can now be used to determine the associated transmission levels from the compressed reception levels:

F11) Ptx_new(i) := Prx(i) * Atten(i)

It may be necessary to reduce the transmission signal power levels if the maximum permissible total power level is exceeded, or it is worthwhile increasing the transmitted signal power levels in order to improve the transmission characteristics. Both are carried out by new transmission-end level matching.

A new transmission-end mean value will be calculated for this purpose:

F12) Ptx_mean_new = Total (Ptx_new(i)/Number of channels)

This is used to establish a transmission-end correction factor;

F13) corfact_tx = Ptx_mean/Ptx_mean_new

The new transmission levels are then calculated:

F14) Ptx(i) = Ptx_new(i)* corfact_tx

This completes the calculation of the dynamic range compression process, and the newly calculated transmission levels are set.

Of course signal failures must be taken into account in the dynamic range compression process, in which case time constants of the control loop are matched to the requirements.

Although modifications and changes may be suggest by those skilled in the art to which this invention pertains, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications that my reasonably and properly come under the scope of their contribution to the art. - -

09/807766
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[Substitute Specification]

{~~Description~~} [- - METHOD FOR CHANNEL-BY-CHANNEL ADJUSTMENT] {~~Method for channel-by-channel adjustment of the~~ }[OF TRANSMITTED SIGNAL POWER LEVELS IN AN OPTICAL WAVELENGTH-DIVISION MULTIPLEX TRANSMISSION SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention:

The present invention pertains to optical wavelength division multiplex transmission systems in general. Specifically, the present invention pertains to adjustment of] transmitted signal power levels in {~~a~~} **[optical]** wavelength {~~-~~}division multiplex transmission {~~system~~} **[systems.**

Discussion of the Related Art:]

Owing to the wavelength dependency of optical amplifiers, optical wavelength-division multiplex transmission systems have losses in the transmission fibers and in passive optical components as well as attenuation levels which differ due to non-linear effects such as signal coupling resulting from stimulated Raman scatter in general for the various signals and channels. In an optical transmission path which comprises a number of path sections having a number of fiber amplifiers, these effects can become additive. As a consequence of this, at the receiving end, the weaker optical signals are no longer detected without faults by the optical receiver since their levels are too low or since their optical signal-to-noise ratio (OSNR) is too low. On the other hand, the maximum permissible input level of the optical receiver may be exceeded by a signal which is attenuated to a lesser extent.

One method, which is used in existing optical transmission systems, for compensating for the different levels or OSNR values is corresponding initial compensation at the transmission end, which is referred to as preemphasis. In this case the level or OSNR distribution of the channels/signals at the reception end is measured using an optical spectrum analyzer, and the level at the transmission end is raised for signals which arrive with severe attenuation at the receiver, while the level of more powerful signals is correspondingly reduced, to ensure that all the received signals have the same power level{(~~level balance~~)}**[, also referred to as level balance,]** or the same **[optical]** signal-to-

noise ratio (OSNR balance) at the reception end. The raising or lowering of the transmitted signal level for each channel or for {

}each transmitted signal is generally selected such that the total transmitted signal power level {~~(~~}**[, that is the]** total of the power levels of all the transmitted signals and {

}of the total signal{~~)~~}**[,]** remains unchanged at the start of the optical path{~~,~~} or does not exceed a maximum value.

Suitable algorithms for level and OSNR balancing are described in the article {~~Equalisation~~}**["Equalization]** in Amplified WDM Lightwave Transmission {~~Systems~~} **[Systems" appearing]** in IEEE Photonics, Technology Letters, Vol. 4, No. 8, August 1992, pages 920 to 922.

However, {~~the following~~} disadvantages can occur if exactly implemented level or OSNR compensation is used{~~:~~}**[. One such disadvantages is that,]** owing to the wavelength dependency of the path loss, complete level balancing for the reception end can lead to an excessively high level dynamic range at the transmitting end{~~, that is to say~~}**[. Hence,]** an excessively large quotient between the maximum and minimum channel power level **[can occur]**. There is then a risk of signals with a raised transmitted power level being distorted by non-linear effects in the fibers and/or of transmitted signals with a greatly reduced level actually falling below the minimum input power level of an optical amplifier, {~~resulting~~} **[which would result]** in considerable signal distortion due to noise.

Complete OSNR balancing for the reception end can also lead to an excessive level dynamic range at the transmitting end. {

}In addition, there is a risk of the maximum permissible input level range of one or more of the connected optical receivers being exceeded or undershot.

A method and {~~an~~} arrangement for adjusting identical signal levels {~~are known from~~} **[is shown in]** US Patent 5,815,299. In {~~this~~} **[the]** method, the average level of all the transmitted signals and the level of the weakest signal are determined. The other signals are attenuated as a function of the difference between the average level and the level of the weakest signal{~~(column 6, lines 56 -~~

~~67)~~}. However, this reduces the average level and thus the quality of all the other channels. Such a method admittedly leads to identical levels in all the {

}channels, but does not optimally utilize the maximum possible dynamic range and thus does not achieve optimum transmission quality or optimum range.

~~The object of the invention is thus, for wavelength division multiplex systems, to specify a method for channel-by-channel adjustment of transmitted signal power levels, in which the transmission-end dynamic range is complied with without unnecessarily adversely affecting the transmission quality. An extended method also takes account of the reception-end dynamic range for exact OSNR balancing.~~

~~The object is achieved by methods which are specified in the independent claims 1 and 4. Advantageous developments of the invention are specified in the dependent claims.~~

}In general, exact level balancing at the reception end is not required, since the connected optical receivers have a considerable level dynamic range in which they operate optimally. In the same way, exact OSNR balancing is not required, provided appropriate system margins are available. In this case, a method {~~is optimal~~} which considers only the dynamic range of the transmitted signals **[would be optimal]**. Since, {~~in general, the~~} systems **[of this type]** operate at an optimum or maximum permissible total power level, it is advantageous for this level to remain constant in any compression of {~~the~~} individual transmitted signal power levels which may be required.

{~~However, for~~} **[For]** OSNR balancing **[however]**, the maximum permissible dynamic range at the reception end must also be checked{~~. If~~}**[, and if]** necessary, the received signal power levels are adapted by compression. This is {~~once again~~} done by changing the power level of the individual transmitted signals{~~. In this case as well,~~ }**[, and]** compliance with the transmission-end dynamic range must be checked once again and, if necessary, changed.

[<u>SUMMARY OF THE INVENTION</u>

It is an object of the present invention to provide a method for channel-by-channel adjustment of transmitted signal power levels in which the transmission-end dynamic range is complied with without unnecessarily adversely affecting the transmission quality.

It is another object of the invention to provide a method for channel-by-channel adjustment of transmitted signal power levels in which reception-end dynamic range for exact OSNR balancing is achieved.

These and other objects of the invention will become apparent from careful review of the following detailed description of the preferred embodiments, which is to be read in conjunction with a review of the accompanying drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS] {~~The invention will be explained in more detail with reference to an exemplary embodiment. In the figures:~~}

Figure 1 shows an exemplary {~~embodiment of a WDM~~} **[wavelength division multiplex]** transmission system with dynamic range compression{~~,~~}**[;]**

Figure 2 shows a flowchart for transmission-end dynamic range compression{~~,~~}**[;]** and

Figure 3 shows a flowchart for reception-end dynamic range compression.

[DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS]

Figure 1 shows {~~the outline~~} **[a]** circuit diagram of a {~~WDM~~} **[wavelength division multiplex (WDM)]** transmission device. **[**

]A transmission terminal TT **[is provided which]** contains {

}a number of optical transmitters TX1 {~~to~~}**[-]** TXn for transmitting data via channels allocated to different wavelengths. {~~The corresponding~~} **[Corresponding]** transmitted signals S1 {~~to~~}**[-]** Sn are passed via adjustable optical attenuators VOA1 to VOAn, and are combined by a multiplexer M to form a wavelength-division multiplex signal WMS. {~~This~~} **[The]** signal **[WMS]** is fed into an optical fiber F and {~~is~~} transmitted via various path sections SA1, SA2 to a receiving terminal RT. Various optical amplifiers V are provided in order to compensate for {~~the~~} attenuation by the optical fibers. **[**

]In the receiving terminal RT, the wavelength division multiplex signal is broken **[** **]**down in a demultiplexer D into individual received signals E1 ~~{to}~~**[-]** En, which are supplied to a respective optical receiver RX1 ~~{to}~~**[-]** RXn.

The wavelength division multiplex signal is split at the reception end by a coupler K, which is connected upstream of the demultiplexer, and is supplied to an optical spectrum analyzer OSA. The level and OSNR values measured by ~~{this}~~ **[the]** optical spectrum analyzer OSA are passed~~{- for example}~~**[,]** via a separate control channel OSC (Optical Supervisory Channel) ~~{-}~~**[for example,]** to a preemphasis controller MD in the transmission terminal. ~~{This}~~ **[The preemphasis controller MD]** comprises a computation device CU and an adjustment device SD which adjusts the transmitted levels of the individual transmitted signals, for example by controlling the output power level of the optical transmitters or, in this case, by adjusting the attenuators. The computation unit can likewise be provided at the reception end.

~~{First of all, let us consider}~~ **[Consider]** the situation in which only the transmission-end dynamic range is adjusted, on the basis of the flowchart **[shown]** in Figure 2. ~~{The individual}~~ **[Individual]** transmitted power levels and received power levels**[,]** or transmitted power levels and reception-end signal-to-noise ratios, for short **[distances,]** the attenuations in the individual channels or the OSNR quality (signal to noise ratio/transmitted power level) generally need to be ~~{known by measurements}~~ **[measured]**.

Firstly, the transmission-end power distribution ~~{(level distribution)}~~ **[also called the level distribution,]** is then calculated for exact level or OSNR balancing at the reception end, based on the transmission characteristics of the individual channels, as described above.

The dynamic range compression can then be started. A first step determines the magnitude of the transmission-end level dynamic range Dtx. This corresponds to the quotient of the maximum level Ptx_max and the minimum level Ptx_min of the transmitted signals, with the term level in this case meaning the power on a linear scale, for example in milliwatts.

F1) Dtx = maximum level from Ptx(i)/minimum level from Ptx(i)

i = 1, 2, ... n - Transmitted signal

A check is then carried out to determine whether the dynamic range Dtx which has been found is greater than the maximum permissible dynamic range Dtx_max. If this is not the case, no dynamic range compression is carried out. However, if this is the case, the next computation step calculates the discrepancy, that is to say the offset, of the individual signal power levels from the mean value Ptx_mean, which has been determined from the optimum or maximum permissible transmitted power level of the transmission-end wavelength division multiplex signal divided by the number of signals.

F2) deltaP_tx(i) := Ptx(i) - Ptx_mean

The next computation step determines the absolute maximum and minimum offset, in other words the offset of the strongest and weakest transmitted signal.

F3) deltaPtx_max := max(deltaPtx(i))

deltaPtx_min := min(deltaPtx(i))

The transmission compression factor is then calculated

F4) compfact_tx := Ptx_mean* (Dtx_max - 1)/

(deltaPtx_max - Dtx_max*deltaPtx_min)

This is then used to calculate the compressed levels using the following formulae:

F5) deltaPtx(i) := deltaPtx(i) * compfact_tx

Ptx(i) := Ptx_mean + deltaP_tx(i)

The dynamic range compression has thus already been calculated and the newly calculated compressed transmission levels Ptx(i) of the transmitted signals S1 to Sn can be set.

If the individual received signals E1 to En are intended to have the same signal-to-noise ratio, that is to say OSNR balancing is assumed, reception-end dynamic range compression can also be carried out, in an extended method as shown in Figure 3. The compression method is once again dependent on the transmission characteristics of each channel being known.

This makes it possible to calculate the transmission-end levels for the individual transmitted signals, the level distribution, for OSNR balancing.

The reception-end dynamic range compression starts by determining the **[** **]**reception-end dynamic range Drx.

F7) Drx:= maximum level from Prx(i)/minimum level from Prx(i)
i = 1, 2, ...,n - Received signal

A check is then carried out to determine whether the maximum permissible reception-end dynamic range Drx is exceeded. If not, there is no need for reception-end dynamic range compression, and the { }calculated signal levels can be set at the transmission end. In general, a check of the maximum permissible transmission-end dynamic range is also required.

If{~~, on the other hand,~~} the maximum permissible reception-end dynamic range Drx is exceeded, then, {~~first of all,~~} the discrepancies, {~~the~~} **[or]** offsets, of the reception-end channel power levels Ptx(i) from the main value Ptx_mean are established:

F7) deltaP_rx(i) := P_rx(i) - P_rx_mean

and the maximum and minimum offsets are determined:

F8) deltaP_rx_max :=max(deltaP_rx(i))
deltaP_rxmin := min(deltaP_rx(i))

The reception-end compression factor is then calculated:

F9) compfact_rx :=Prx_mean*(Drx_max - 1)

/(deltaPrx_max - Drx_max * deltaPrx_min

The compressed reception levels are then determined:

F10) Prx(i) := Prx_mean * deltaPrx(i) * compfact_rx

The already determined channel-specific path loss Atten(i) can now be used to determine the associated transmission levels from the compressed reception levels:

F11) Ptx_new(i) := Prx(i) * Atten(i)

It may be necessary to reduce the transmission signal power levels if the maximum permissible total power level is exceeded, or it is worthwhile increasing the transmitted signal power levels {

}in order to improve the transmission characteristics. Both are carried out by new transmission-end level matching.

A new transmission-end mean value will be calculated for this purpose:

F12) Ptx_mean_new = Total (Ptx_new(i)/Number of channels)

This is used to establish a transmission-end correction factor;

F13) corfact_tx = Ptx_mean/Ptx_mean_new

The new transmission levels are then calculated:

F14) Ptx(i) = Ptx_new(i)* corfact_tx

This completes the calculation of the dynamic range compression process, and the newly calculated transmission levels are set.

{~~Signal~~} **[Of course signal]** failures must{~~, of course,~~} be taken into account in the dynamic range compression process{~~. The~~}**[, in which case]** time constants of the control loop are matched to the requirements.

[Although modifications and changes may be suggest by those skilled in the art to which this invention pertains, it is the intention of the inventors to embody within the patent warranted hereon all changes and modifications that my reasonably and properly come under the scope of their contribution to the art. - -]

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OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY - CHAPTER II

CHANGE OF ADDRESS OF APPLICANTS' REPRESENTATIVE

APPLICANT(S):	WEISKE, et al.
ATTORNEY DOCKET NO:	P01,0059
INTERNATIONAL APPLICATION NO:	PCT/DE99/03178
INTERNATIONAL FILING DATE:	1 OCT 1999
INVENTION:	METHOD FOR CHANNEL-BY CHANNEL ADJUSTMENT OF TRANSMITTED SIGNAL POWER IN AN OPTICAL WAVELENGTH-DIVISION MULTIPLEX TRANSMISSION SYSTEM

Assistant Commissioner for Patents,
Washington, D.C. 20231

Sir:

Members of the firm of Hill & Simpson designated on the original Power of Attorney have merged into the firm of Schiff Hardin & Waite. All future correspondence for the above-referenced application therefore should be sent to the following address:

SCHIFF HARDIN & WAITE
Patent Department
6600 Sears Tower
Chicago, Illinois 60606-6473

CUSTOMER NUMBER 26574

Submitted by,

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Description

Method for channel-by-channel adjustment of the transmitted signal power levels in a wavelength-division multiplex transmission system

Owing to the wavelength dependency of optical amplifiers, optical wavelength-division multiplex transmission systems have losses in the transmission fibers and in passive optical components as well as attenuation levels which differ due to non-linear effects such as signal coupling resulting from stimulated Raman scatter in general for the various signals and channels. In an optical transmission path which comprises a number of path sections having a number of fiber amplifiers, these effects can become additive. As a consequence of this, at the receiving end, the weaker optical signals are no longer detected without faults by the optical receiver since their levels are too low or since their optical signal-to-noise ratio (OSNR) is too low. On the other hand, the maximum permissible input level of the optical receiver may be exceeded by a signal which is attenuated to a lesser extent.

One method, which is used in existing optical transmission systems, for compensating for the different levels or OSNR values is corresponding initial compensation at the transmission end, which is referred to as preemphasis. In this case the level or OSNR distribution of the channels/signals at the reception end is measured using an optical spectrum analyzer, and the level at the transmission end is raised for signals which arrive with severe attenuation at the receiver, while the level of more powerful signals is correspondingly reduced, to ensure that all the received signals have the same power level (level balance) or the same signal-to-noise ratio (OSNR balance) at the reception end. The raising or lowering of the transmitted signal level for each channel or for

each transmitted signal is generally selected such that the total transmitted signal power level (total of the power levels of all the transmitted signals and

of the total signal) remains unchanged at the start of the optical path, or does not exceed a maximum value.

Suitable algorithms for level and OSNR balancing are described in the article Equalisation in Amplified WDM Lightwave Transmission Systems in IEEE Photonics, Technology Letters, Vol. 4, No. 8, August 1992, pages 920 to 922.

However, the following disadvantages can occur if exactly implemented level or OSNR compensation is used: owing to the wavelength dependency of the path loss, complete level balancing for the reception end can lead to an excessively high level dynamic range at the transmitting end, that is to say an excessively large quotient between the maximum and minimum channel power level. There is then a risk of signals with a raised transmitted power level being distorted by non-linear effects in the fibers and/or of transmitted signals with a greatly reduced level actually falling below the minimum input power level of an optical amplifier, resulting in considerable signal distortion due to noise.

Complete OSNR balancing for the reception end can also lead to an excessive level dynamic range at the transmitting end.

In addition, there is a risk of the maximum permissible input level range of one or more of the connected optical receivers being exceeded or undershot.

A method and an arrangement for adjusting identical signal levels are known from US Patent 5,815,299. In this method, the average level of all the transmitted signals and the level of the weakest signal are determined. The other signals are attenuated as a function of the difference between the average level and the level of the weakest signal (column 6, lines 56 - 67). However, this reduces the average level and thus the quality of all the other channels. Such a method admittedly leads to identical levels in all the

channels, but does not optimally utilize the maximum possible dynamic range and thus does not achieve optimum transmission quality or optimum range.

The object of the invention is thus, for wavelength division multiplex systems, to specify a method for channel-by-channel adjustment of transmitted signal power levels, in which the transmission-end dynamic range is complied with without unnecessarily adversely affecting the transmission quality. An extended method also takes account of the reception-end dynamic range for exact OSNR balancing.

The object is achieved by methods which are specified in the independent claims 1 and 4.

Advantageous developments of the invention are specified in the dependent claims.

In general, exact level balancing at the reception end is not required, since the connected optical receivers have a considerable level dynamic range in which they operate optimally. In the same way, exact OSNR balancing is not required, provided appropriate system margins are available. In this case, a method is optimal which considers only the dynamic range of the transmitted signals. Since, in general, the systems operate at an optimum or maximum permissible total power level, it is advantageous for this level to remain constant in any compression of the individual transmitted signal power levels which may be required.

However, for OSNR balancing, the maximum permissible dynamic range at the reception end must also be checked. If necessary, the received signal power levels are adapted by compression. This is once again done by changing the power level of the individual transmitted signals. In this case as well, compliance with the transmission-end dynamic range must be checked once again and, if necessary, changed.

The invention will be explained in more detail with reference to an exemplary embodiment. In the figures:

Figure 1 shows an exemplary embodiment of a WDM transmission system with dynamic range compression,

Figure 2 shows a flowchart for transmission-end dynamic range compression, and

Figure 3 shows a flowchart for reception-end dynamic range compression.

Figure 1 shows the outline circuit diagram of a WDM transmission device. A transmission terminal TT contains

a number of optical transmitters TX1 to TXn for transmitting data via channels allocated to different wavelengths. The corresponding transmitted signals S1 to Sn are passed via adjustable optical attenuators VOA1 to VOAn, and are combined by a multiplexer M to form a wavelength-division multiplex signal WMS. This signal is fed into an optical fiber F and is transmitted via various path sections SA1, SA2 to a receiving terminal RT. Various optical amplifiers V are provided in order to compensate for the attenuation by the optical fibers. In the receiving terminal RT, the wavelength division multiplex signal is broken down in a demultiplexer D into individual received signals E1 to En, which are supplied to a respective optical receiver RX1 to RXn.

The wavelength division multiplex signal is split at the reception end by a coupler K, which is connected upstream of the demultiplexer, and is supplied to an optical spectrum analyzer OSA. The level and OSNR values measured by this optical spectrum analyzer OSA are passed - for example via a separate control channel OSC (Optical Supervisory Channel) - to a preemphasis controller MD in the transmission terminal. This comprises a computation device CU and an adjustment device SD which adjusts the transmitted levels of the individual transmitted signals, for example by controlling the output power level of the optical transmitters or, in this case, by adjusting the attenuators. The computation unit can likewise be provided at the reception end.

First of all, let us consider the situation in which only the transmission-end dynamic range is adjusted, on the basis of the flowchart in **Figure 2**. The individual transmitted power levels and received power levels or transmitted power levels and reception-end signal-to-noise ratios, for short the attenuations in the individual channels or the OSNR quality (signal to noise ratio/transmitted power level) generally need to be known by measurements.

Firstly, the transmission-end power distribution (level distribution) is then calculated for exact level or OSNR balancing at the reception end, based on the transmission characteristics of the individual channels, as described above.

The dynamic range compression can then be started. A first step determines the magnitude of the transmission-end level dynamic range Dtx. This corresponds to the quotient of the maximum level Ptx_max and the minimum level Ptx_min of the transmitted signals, with the term level in this case meaning the power on a linear scale, for example in milliwatts.

F1) $Dtx = \text{maximum level from } Ptx(i) / \text{minimum level from } Ptx(i)$

$i = 1, 2, \ldots n$ - Transmitted signal

A check is then carried out to determine whether the dynamic range Dtx which has been found is greater than the maximum permissible dynamic range Dtx_max. If this is not the case, no dynamic range compression is carried out. However, if this is the case, the next computation step calculates the discrepancy, that is to say the offset, of the individual signal power levels from the mean value Ptx_mean, which has been determined from the optimum or maximum permissible transmitted power level of the transmission-end wavelength division multiplex signal divided by the number of signals.

F2) $deltaP\_tx(i) := Ptx(i) - Ptx\_mean$

The next computation step determines the absolute maximum and minimum offset, in other words the offset of the strongest and weakest transmitted signal.

F3) $deltaPtx\_max := \max(deltaPtx(i))$

$deltaPtx\_min := \min(deltaPtx(i))$

The transmission compression factor is then calculated

F4) compfact_tx := Ptx_mean* (Dtx_max - 1)/
(deltaPtx_max - Dtx_max*deltaPtx_min)

This is then used to calculate the compressed levels using the following formulae:

F5) deltaPtx(i) := deltaPtx(i) * compfact_tx
Ptx(i) := Ptx_mean + deltaP_tx(i)

The dynamic range compression has thus already been calculated and the newly calculated compressed transmission levels Ptx(i) of the transmitted signals S1 to Sn can be set.

If the individual received signals E1 to En are intended to have the same signal-to-noise ratio, that is to say OSNR balancing is assumed, reception-end dynamic range compression can also be carried out, in an extended method as shown in **Figure 3**. The compression method is once again dependent on the transmission characteristics of each channel being known.

This makes it possible to calculate the transmission-end levels for the individual transmitted signals, the level distribution, for OSNR balancing.

The reception-end dynamic range compression starts by determining the reception-end dynamic range Drx.

F7) Drx:= maximum level from Prx(i)/minimum level from Prx(i)
i = 1, 2, ...,n - Received signal

A check is then carried out to determine whether the maximum permissible reception-end dynamic range Drx is exceeded. If not, there is no need for reception-end dynamic range compression, and the

calculated signal levels can be set at the transmission end. In general, a check of the maximum permissible transmission-end dynamic range is also required.

If, on the other hand, the maximum permissible reception-end dynamic range Drx is exceeded, then, first of all, the discrepancies, the offsets, of the reception-end channel power levels Ptx(i) from the main value Ptx_mean are established:

F7) $$\text{deltaP\_rx}(i) := \text{P\_rx}(i) - \text{P\_rx\_mean}$$

and the maximum and minimum offsets are determined:

F8) $$\text{deltaP\_rx\_max} := \max(\text{deltaP\_rx}(i))$$
$$\text{deltaP\_rxmin} := \min(\text{deltaP\_rx}(i))$$

The reception-end compression factor is then calculated:

F9) $$\text{compfact\_rx} := \text{Prx\_mean} * (\text{Drx\_max} - 1) / (\text{deltaPrx\_max} - \text{Drx\_max} * \text{deltaPrx\_min}$$

The compressed reception levels are then determined:

F10) $$\text{Prx}(i) := \text{Prx\_mean} * \text{deltaPrx}(i) * \text{compfact\_rx}$$

The already determined channel-specific path loss Atten(i) can now be used to determine the associated transmission levels from the compressed reception levels:

F11) $$\text{Ptx\_new}(i) := \text{Prx}(i) * \text{Atten}(i)$$

It may be necessary to reduce the transmission signal power levels if the maximum permissible total power level is exceeded, or it is worthwhile increasing the transmitted signal power levels

in order to improve the transmission characteristics. Both are carried out by new transmission-end level matching.

A new transmission-end mean value will be calculated for this purpose:

F12) Ptx_mean_new = Total (Ptx_new(i)/Number of channels)

This is used to establish a transmission-end correction factor;

F13) corfact_tx = Ptx_mean/Ptx_mean_new

The new transmission levels are then calculated:

F14) Ptx(i) = Ptx_new(i)* corfact_tx

This completes the calculation of the dynamic range compression process, and the newly calculated transmission levels are set.

Signal failures must, of course, be taken into account in the dynamic range compression process. The time constants of the control loop are matched to the requirements.

Patent Claims

1. A method for channel-specific adjustment of transmitted signal power levels in a wavelength-division multiplex transmission system,
in which the transmission characteristics for each transmission channel are determined and
if the signal power levels or the signal-to-noise ratios of the individual received signals (E1 to En) are the same, the signal power levels of the associated transmitted signals (S1 to Sn) are determined on a channel-specific basis,
characterized
in that the transmission-end dynamic range (Dtx) is determined,
in that, if the maximum permissible dynamic range (Dtx_max) at the transmission end is exceeded, the individual power discrepancies (delta Ptx(i), i = 1, 2, ...n) of the transmitted signals (S1 to Sn) from the mean transmitted signal power level (Ptx_mean) are determined and the individual power discrepancies of the transmitted signals (S1 to Sn) are reduced by calculation, using a transmission compression factor (compfact_tx), which is the same for all the transmitted signals (S1 to Sn), in such a manner that the maximum permissible dynamic range is complied with,
in that the required transmission signal power levels (Ptx_new(i)) are recalculated, and
in that the newly calculated compressed transmitted signal power levels (Ptx_new(i)) are set.

2. The method as claimed in claim 1,
characterized
in that the total maximum permissible total transmitted signal power level of all the transmitted signals (S1 to Sn) is kept at least approximately constant.

3. The method as claimed in claim 1 or 2,
characterized
in that the transmitted signal power levels (Ptx(i)) of the transmitted signals (S1 to Sn) and transmission-end

values (Dtx,

delta Ptx(i), Ptx_mean) derived from them are determined by measuring the received signal power levels of the received signals (E1 to En) and from the transmission characteristics of the transmission channels.

4. A method for channel-specific adjustment of transmitted signal power levels in a wavelength-division multiplex transmission systems,
in which the transmission characteristics for each transmission channel are determined and
if the signal-to-noise ratios of the individual received signals (E1 to En) are the same, the power levels (Ptx(i)) of the associated transmitted signals (S1 to Sn) are determined on a channel-specific basis,
characterized
in that the reception-end dynamic range (Drx) is determined,
in that, if the maximum permissible reception-end dynamic range (Drx_max) is exceeded, the individual power discrepancies (delta Prx(i), i = 1, 2, ...n) of the transmitted signal power levels from the mean received power level (Ptx_mean) are determined, and the individual power discrepancies of the received signals (E1 to En) are reduced by calculation using a compression factor (compfact_rx) which is the same for all the received signals (E1 to En), in such a manner that the maximum permissible dynamic range at the reception end is complied with,
in that the required new transmitted signal power levels (Ptx_new(i)) are calculated,
in that, if necessary, transmission-end power correction is carried using a transmission-end correction factor (corfact_tx) which needs to be calculated, and
in that the newly calculated compressed transmission signal power levels (Ptx_new(i); Ptx(i)) are set.

5. The method as claimed in claim 4,
characterized

in that the total received signal power level (Prx_mean) of all the received signals (E1 to En) and/or the total transmitted signal

power level (Ptx_mean) of all the transmitted signals (S1 to Sn) is kept at least approximately constant.

6. The method as claimed in claim 4 or 5, characterized in that the transmitted signal power levels (Ptx(i)) of the transmitted signals (S1 to Sn) and transmission-end values (Dtx, delta Ptx(i), Ptx_mean), derived from them, are determined by measurement of the received signal power levels of the received signals (E1 to En) and from the transmission characteristics of the transmission channels.

7. The method as claimed in claim 6, characterized in that the transmission-end correction factor (corfact_tx) is calculated from the ratio of the previous transmission-end mean level value (Ptx_mean) to a transmission-end mean level value (Ptx_mean_new) determined from the required new transmitted signal power level (Ptx_new(i)), and in that the individual signal power levels (Ptx(i)) of the transmitted signals (S1 to Sn) are changed using this transmission-end correction factor (corfact_tx), which is the same for all the transmitted signals (S1 to Sn), in such a manner that the total maximum permissible total transmitted signal power level of all the transmitted signals (S1 to Sn) is kept at least approximately constant.

Abstract

Method for channel-by-channel adjustment of the transmitted signal power levels in a wavelength-division multiplex transmission system

For exact level balancing or signal-to-noise ratio balancing of received signals (E1 to En), the associated transmitted signal power levels (Ptx(i)) are adjusted. If the maximum permissible dynamic range is exceeded, the individual transmitted signal power levels are compressed, with the total transmitted signal power level being kept at least approximately constant.

Figure 1

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IN THE UNITED STATES DESIGNATED/ELECTED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY – CHAPTER II

SUBMISSION OF DRAWINGS

APPLICANT(S):	WEISKE, et al.
ATTORNEY DOCKET NO:	P01,0059
INTERNATIONAL APPLICATION NO:	PCT/DE99/03178
INTERNATIONAL FILING DATE:	1 OCT 1999
INVENTION:	METHOD FOR CHANNEL-BY-CHANNEL ADJUSTMENT OF TRANSMITTED SIGNAL POWER IN AN OPTICAL WAVELENGTH-DIVISION MULTIPLEX TRANSMISSION SYSTEM

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

Applicants herewith submit five drawing sheets, showing Figures 1, 2A, 2B, 3A, and 3B, in the captioned PCT application.

Respectfully submitted,

Steven H. Noll

Steven H. Noll (Reg. No. 28,982)

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Attorneys for Applicant(s)

Customer Number: 26574

FIG 1

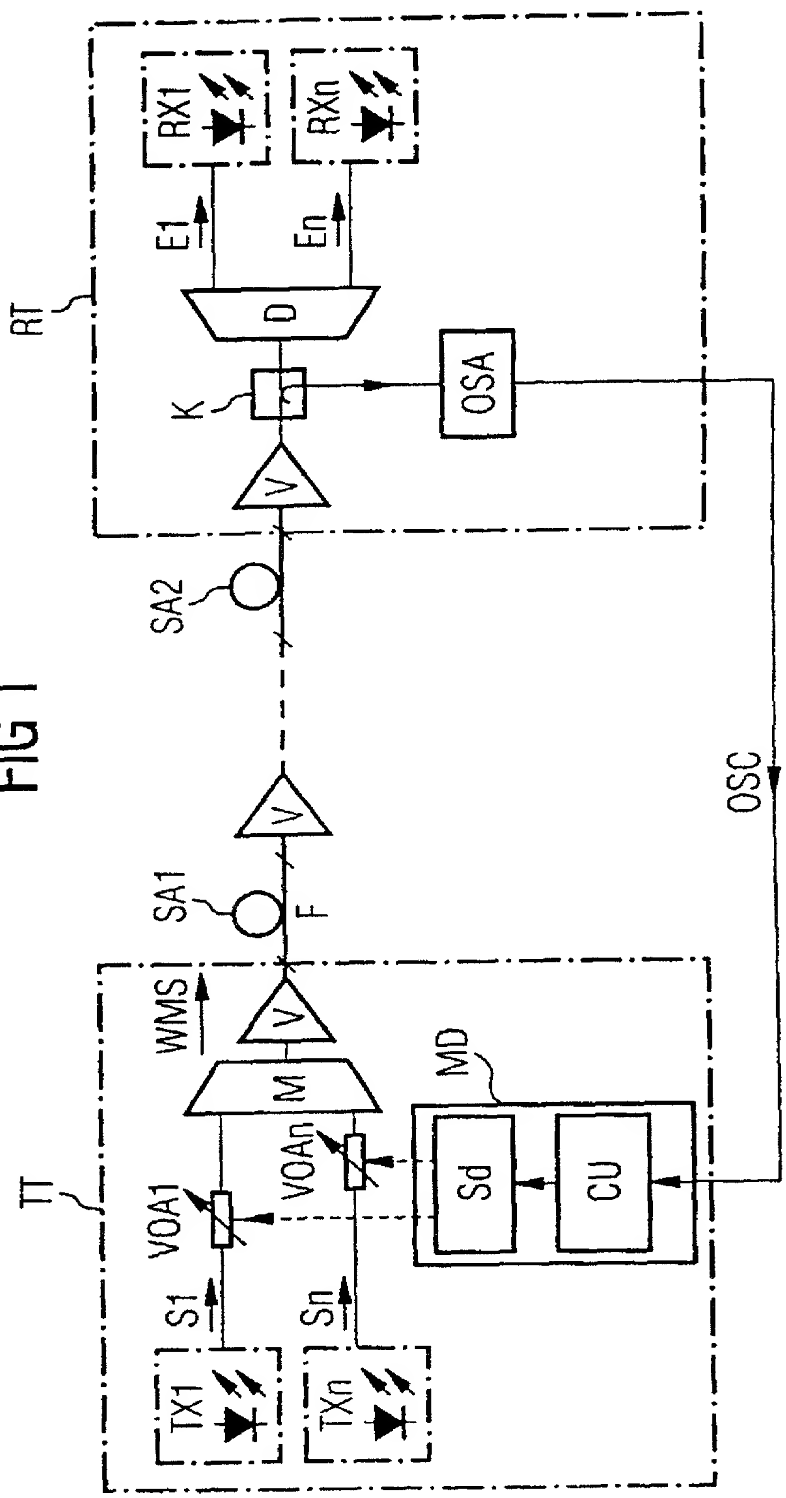

RT
RX1
RXn
E1
En
D
K
OSA
V
SA2
OSC
V
SA1
F
WMS
V
M
MD
Sd
CU
TT
VOA1
VOAn
S1
Sn
TX1
TXn

FIG 2A

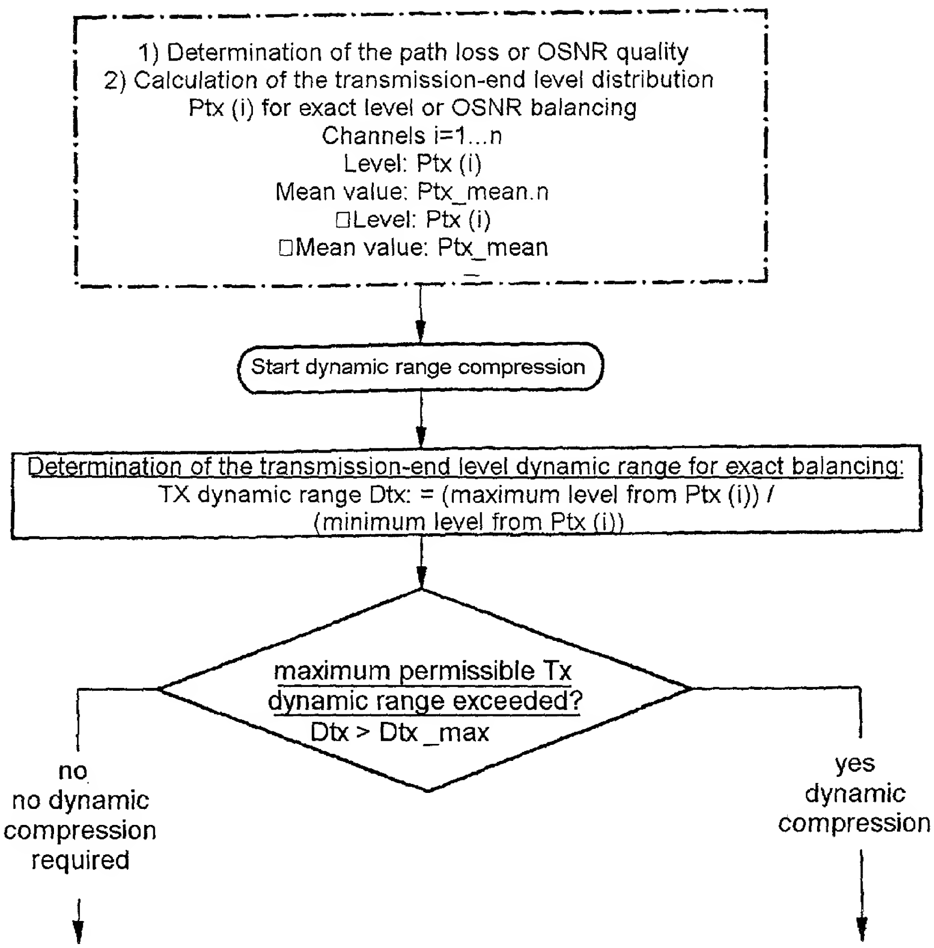

1) Determination of the path loss or OSNR quality
2) Calculation of the transmission-end level distribution
Ptx (i) for exact level or OSNR balancing
Channels i=1...n
Level: Ptx (i)
Mean value: Ptx_mean.n
□Level: Ptx (i)
□Mean value: Ptx_mean
Start dynamic range compression
Determination of the transmission-end level dynamic range for exact balancing:
TX dynamic range Dtx: = (maximum level from Ptx (i)) /
(minimum level from Ptx (i))
maximum permissible Tx
dynamic range exceeded?
Dtx > Dtx _max
no
no dynamic
compression
required
yes
dynamic
compression

FIG 2B

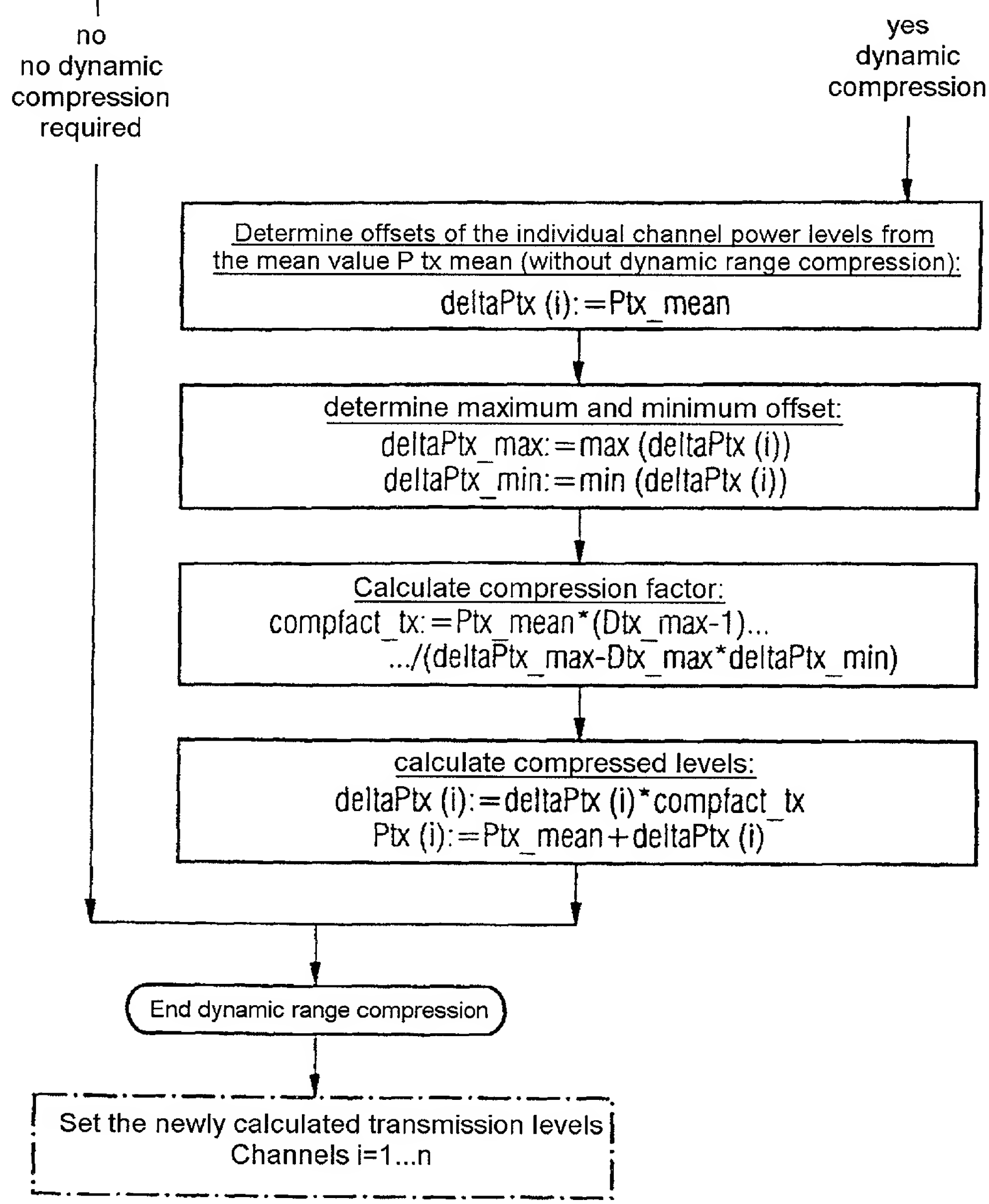
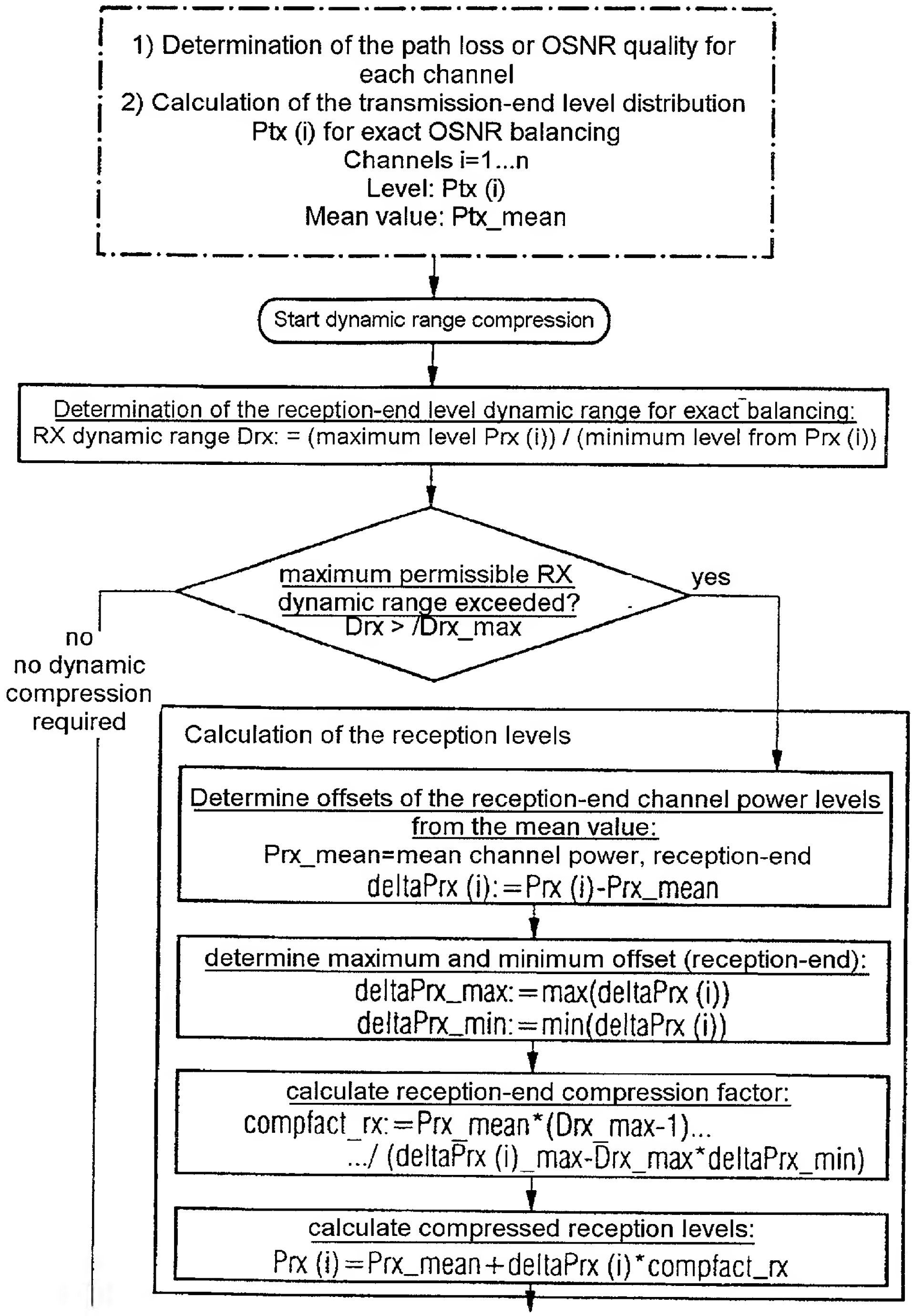
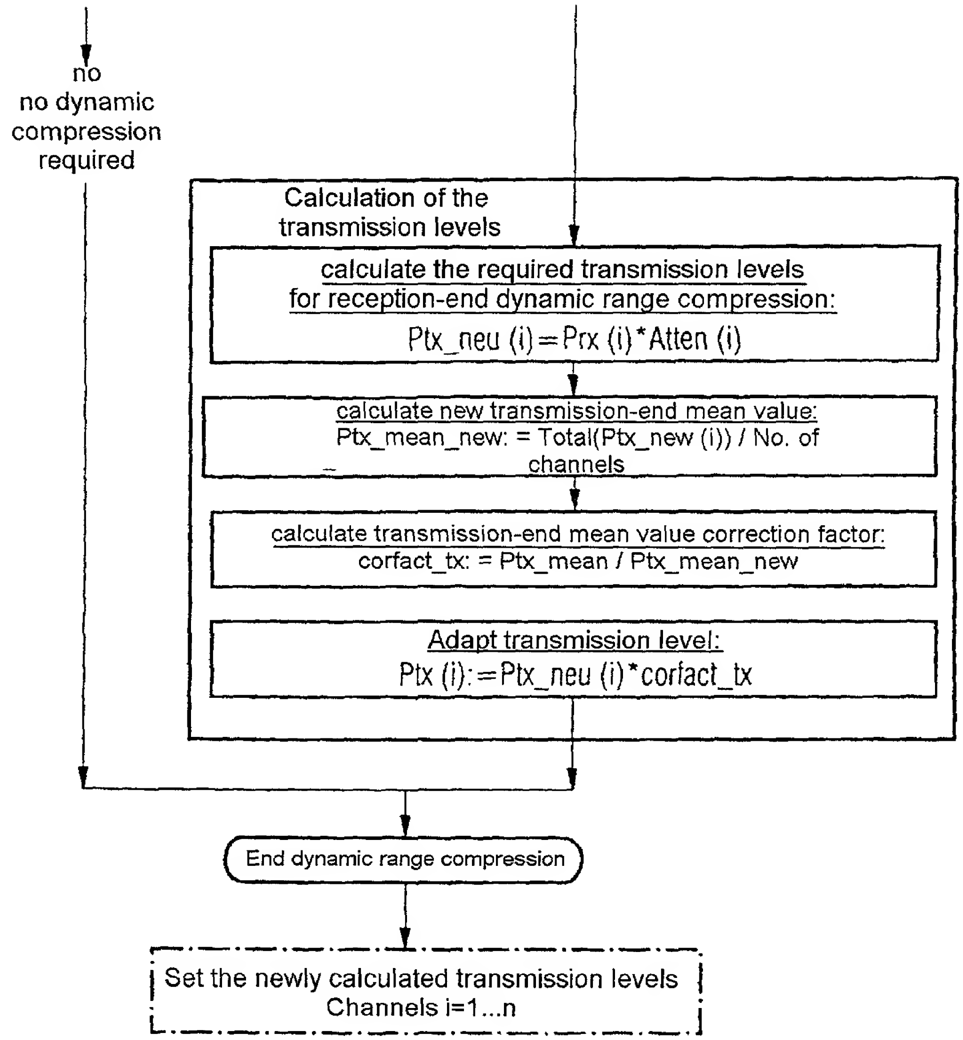

no
no dynamic
compression
required
yes
dynamic
compression
Determine offsets of the individual channel power levels from the mean value P tx mean (without dynamic range compression):
deltaPtx (i):=Ptx_mean
determine maximum and minimum offset:
deltaPtx_max:=max (deltaPtx (i))
deltaPtx_min:=min (deltaPtx (i))
Calculate compression factor:
compfact_tx:=Ptx_mean*(Dtx_max-1)...
.../(deltaPtx_max-Dtx_max*deltaPtx_min)
calculate compressed levels:
deltaPtx (i):=deltaPtx (i)*compfact_tx
Ptx (i):=Ptx_mean+deltaPtx (i)
End dynamic range compression
Set the newly calculated transmission levels
Channels i=1...n

FIG 3A



1) Determination of the path loss or OSNR quality for each channel
2) Calculation of the transmission-end level distribution Ptx (i) for exact OSNR balancing
Channels i=1...n
Level: Ptx (i)
Mean value: Ptx_mean
Start dynamic range compression
Determination of the reception-end level dynamic range for exact balancing:
RX dynamic range Drx: = (maximum level Prx (i)) / (minimum level from Prx (i))
maximum permissible RX dynamic range exceeded?
Drx > /Drx_max
yes
no
no dynamic compression required
Calculation of the reception levels
Determine offsets of the reception-end channel power levels from the mean value:
Prx_mean=mean channel power, reception-end
deltaPrx (i):=Prx (i)-Prx_mean
determine maximum and minimum offset (reception-end):
deltaPrx_max:=max(deltaPrx (i))
deltaPrx_min:=min(deltaPrx (i))
calculate reception-end compression factor:
compfact_rx:=Prx_mean*(Drx_max-1)...
.../ (deltaPrx (i)_max-Drx_max*deltaPrx_min)
calculate compressed reception levels:
Prx (i)=Prx_mean+deltaPrx (i)*compfact_rx

FIG 3B


no
no dynamic compression required
Calculation of the transmission levels
calculate the required transmission levels for reception-end dynamic range compression:
Ptx_neu (i) = Prx (i) * Atten (i)
calculate new transmission-end mean value:
Ptx_mean_new: = Total(Ptx_new (i)) / No. of channels
calculate transmission-end mean value correction factor:
corfact_tx: = Ptx_mean / Ptx_mean_new
Adapt transmission level:
Ptx (i): = Ptx_neu (i) * corfact_tx
End dynamic range compression
Set the newly calculated transmission levels
Channels i=1...n

Declaration and Power of Attorney For Patent Application
Erklärung Für Patentanmeldungen Mit Vollmacht
German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

As a below named inventor, I hereby declare that:

dass mein Wohnsitz, meine Postanschrift, und meine Staatsangehörigkeit den im Nachstehenden nach meinem Namen aufgeführten Angaben entsprechen,

My residence, post office address and citizenship are as stated below next to my name,

dass ich, nach bestem Wissen der ursprüngliche, erste und alleinige Erfinder (falls nachstehend nur ein Name angegeben ist) oder ein ursprünglicher, erster und Miterfinder (falls nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin, für den dieser Antrag gestellt wird und für den ein Patent beantragt wird für die Erfindung mit dem Titel:

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Verfahren zur kanalweisen Einstellung von Sendesignalleistungen eines Wellenlängenmultiplex-Übertragungssystems

____

deren Beschreibung

the specification of which

(zutreffendjhaes ankreuzen)

(check one)

☒ hier beigefügt ist.

☐ is attached hereto.

☐ am ________________ als
PCT internationale Anmeldung
PCT Anmeldungsnummer ________________
Eingereicht wurde und am ________________
Abgeändert wurde (falls tatsächlich abgeändert).

☐ was filed on ________________ as
PCT international application
PCT Application No. ________________
and was amended on ________________
(if applicable)

Ich bestätige hiermit, dass ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäss Abschnitt 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 119 aller unten angegebenen Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde, und habe auch alle Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde nachstehend gekennzeichnet, die ein Anmeldedatum haben, das vor dem Anmeldedatum der Anmeldung liegt, für die Priorität beansprucht wird

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

German Language Declaration

Prior foreign appplications
Priorität beansprucht

Priority Claimed

198 48 989.7	Germany	23. Oktober 1998	☒ Yes / Ja	☐ No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		
			☐ Yes / Ja	☐ No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		
			☐ Yes / Ja	☐ No / Nein
(Number) (Nummer)	(Country) (Land)	(Day Month Year Filed) (Tag Monat Jahr eingereicht)		

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozeßordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35. United States Code. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occured between the filing date of the prior application and the national or PCT international filing date of this application.

(Application Serial No.) (Anmeldeseriennummer)	(Filing Date) (Anmeldedatum)	(Status) (patentiert, anhängig, aufgegeben)	(Status) (patented, pending, abandoned)
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date) (Anmeldedatum)	(Status) (patentiert, anhängig, aufgeben)	(Status) (patented, pending, abandoned)

Ich erkläre hiermit, dass alle von mir in der vorliegenden Erklärung gemachten Angaben nach meinem besten Wissen und Gewissen der vollen Wahrheit entsprechen, und dass ich diese eidesstattliche Erklärung in Kenntnis dessen abgebe, dass wissentlich und vorsätzlich falsche Angaben gemäss Paragraph 1001, Absatz 18 der Zivilprozessordnung der Vereinigten Staaten von Amerika mit Geldstrafe belegt und/oder Gefängnis bestraft werden koennen, und dass derartig wissentlich und vorsätzlich falsche Angaben die Gültigkeit der vorliegenden Patentanmeldung oder eines darauf erteilten Patentes gefährden können.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

German Language Declaration

VERTRETUNGSVOLLMACHT: Als benannter Erfinder beauftrage ich hiermit den nachstehend benannten Patentanwalt (oder die nachstehend benannten Patentanwälte) und/oder Patent-Agenten mit der Verfolgung der vorliegenden Patentanmeldung sowie mit der Abwicklung aller damit verbundenen Geschafte vor dem Patent- und Warenzeichenamt: *(Name und Registrationsnummer anführen)*

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

(19)

And I hereby appoint

Messrs. John D. Simpson (Registration No. 19,842) Lewis T. Steadman ~~(17,074)~~, William C. Stueber ~~(16,453)~~, P. Phillips Connor (19,259), Dennis A. Gross (24,410), Marvin Moody (16,549), Steven H. Noll (28,982), Brett A. Valiquet (27,841), Thomas I. Ross (29,275), Kevin W. Guynn (29,927), Edward A Lehmann (22,312), James D. Hobart (24,149), Robert M. Barrett ~~(30,142)~~, James Van Santen (16,584), J. Arthur Gross (13,615), Richard J. Schwarz ~~(13,472)~~ and Melvin A. Robinson (31,870), David R. Metzger (32,919), John R. Garrett (27,888) all members of the firm of Hill, Steadman & Simpson, A Professional Corporation.

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(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).

(Supply similar information and signature for third and subsequent joint inventors).